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Winter Injury as Related to Fall and Winter Growth and Crown-Rust Infection in Oat Varieties and Their Hybrids

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WINTER INJURY AS RELATED TO FALL AND WINTER GROWTH AND CROWN-RUST INFECTION IN OAT VARIETIES AND THEIR HYBRIDS

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Destructive epidemics of crown rust and a lack of hardiness in many commercial oat varieties have often reduced yields of winter oats in Arkansas to such an extent that spring oats have largely been used, despite the fact that such oats usually produce much lower yields than winter oats. Aside from higher grain yields, winter oats offer a distinct advantage over spring oats by providing a source of winter pasture and permitting a second crop, such as lespedeza, to be more readily grown in the same field. The relatively low yields of oats have contributed to a frequent shortage of home-grown feed.

To overcome the problem of losses resulting from crown rust and lack of hardiness, oat varieties have been hybridized in an attempt to combine resistance to rusts and smuts with sufficient growth to yield good winter pasture, and with sufficient hardiness to protect the winter growth and enable the production of adequate hay or grain yields. From the results of 2 years of hardiness tests it was concluded that "some of the hybrids possess as much hardiness as the hardiest parents." [2]

Selections from these oat hybrids have now passed through one of the coldest winters on record in Arkansas, and also through a severe cold period in the following November, the latter occurring during an epidemic of crown rust.

Murphy [3] has shown that when hardy oat varieties are artificially inoculated with either crown rust or stem rust and subjected to artificial freezing, they lose their hardiness in proportion to the amount of rust infection. The crown-rust epidemic in the fall of 1940 provided an opportunity to determine the effect of this rust on winter hardiness under field conditions.

[1] Resigned, effective February 7, 1942.

[2] Rosen, H. R., Weetman, L. M., and McClelland, C. K., "Hybridizing Oats to Combine Growth for Winter Pasture, Hardiness, and Resistance to Rusts and Smuts." Amer. Soc. Agron. Jour. 32: 12-14. 1940.

[3] Murphy, H. C., "Effect of Crown and Stem Rusts on the Relative Cold Resistance of Varieties and Selections of Oats." Phytopathology 29: 763-782. 1939.

Injury During Winter of 1939-40

During the winter of 1939-40 some 6,000 selections of oat hybrids, produced by the writers, were growing at the Main Experiment Station.[4]

Temperature records of the Main Station for the fall, winter, and early spring months in which frosts occurred in 1939-40 are presented in Table 1. Since soil moisture may have influenced hardiness, the rainfall for these months is also given.

Table 1. Temperature and Rainfall for Selected Months, Main Experiment Station, 1939-40 [1]

Year and month	Temperature						Rainfall
	Mean	High	Low	Mean maximum	Mean minimum	Departure from normal	
	Degrees F.	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Degrees F.*	*Inches*
1939							
October	64.4	91	26	77.7	51.0	+ 3.6	3.60
November	46.4	75	22	56.7	36.1	— 3.1	3.30
December	44.4	72	14	54.0	34.7	+ 4.4	1.17
1940							
January	23.4	51	— 7	32.9	14.0	— 15.0	.79
February	39.4	71	18	48.4	30.4	— 1.0	1.57
March	50.0	83	22	62.0	37.9	— .5	1.80
April	57.4	87	24	67.8	47.0	— 1.0	6.57

[1] Data from U. S. Weather Bureau records.

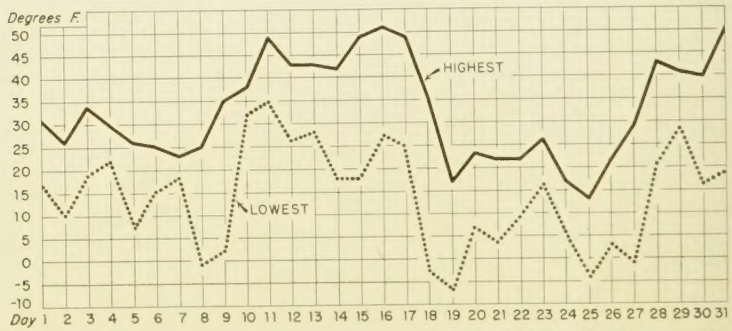

Figure 1. Daily temperature records of the Main Experiment Station for January, 1940.

[4] Over 2,000 additional selections were growing at the Rice Branch Experiment Station. There was comparatively little winterkilling at this station.

Most of the injury to oats at the Main Station occurred in January, 1940. Daily temperatures for this month are presented in Figure 1. On 29 days of the month the minimum temperature was below freezing; on 5 days of the 29 it was below 0° F. The total snowfall for January was 9.1 inches, most of which disappeared quickly, and there was no snow on the ground when the temperature was lowest (−7° F.). Therefore, the protective effects of heavy snow blankets were very slight or absent in this particular month.

Because of the many selections, it was practically impossible to obtain accurate percentage data on autumn stand or on spring survival. Likewise, the limited replications of many of the hybrids and parents made it inadvisable to present the data statistically. All parents and hybrids were grown in 10-foot rows that were one foot apart. Many of the hybrids were grown in single triplicate randomized rows, some in four to 12 rows, while many

TABLE 2. ESTIMATED PERCENTAGES OF LEAF AREAS KILLED AND WINTER SURVIVAL OF PARENT OAT VARIETIES USED IN BREEDING, MAIN EXPERIMENT STATION, WINTER OF 1939-40

Variety or selection	Leaf area killed	Survival
	Per cent	*Per cent*
Tennex C. I. 3169 (Tennessee 1884)	85	28
Tennessee 1922 C. I. 3171	90	20
Fulwin C. I. 3168 (Tennessee 1945)	85	16
Fulghum × Victoria (Stanton Block 97xyz 1935-36)	90	16
Oklahoma 2900 (selection of Hairy Culberson × Fulghum winter type)	90	14
Custis C. I. 2041	95	14
Coker 32-1 C. I. 3026	90	13
Lee C. I. 2042	98	10
Oklahoma 2898 (selection of Hairy Culberson × Fulghum winter type)	90	8
Hairy Culberson C. I. 2505	90	8
Fulghum C. I. 3233	95	7
Fulghum C. I. 3232	95	4
Coker Fulgrain 33-19 C. I. 3253	95	3
Lee × Bond XS1121a (Adair-Ark. X26)	98	1
Texas 1415-12 (selection of Red Rustproof)	98	0
Nortex C. I. 2382	100	0
Ferguson 922 C. I. 2150	100	0
Mutica Ukraina C. I. 3259	100	0
Bond C. I. 2733	100	0
Victoria C. I. 2401	100	0
Boone C. I. 3305 (Victoria × Richland)	100	0
Victoria × Richland C. I. 3310	100	0
Victoria × Richland C. I. 3313	100	0
Bond × Iogold Iowa 4097	100	0

others occupied but one row. Each parent was grown in a plot of three adjoining rows. The rate of planting for the parents was 7 gm. per row (about 2 bushels per acre), whereas for the selections the rate varied from 3 to 7 gm. per row. The seed was hand-sown in open furrows and covered with a hoe. The main planting was made September 15 to 30, with a duplicate planting of 393 selections October 19.

In estimating the autumn stand, time permitted the accurate counting of plants in only a few rows. Such counts, however,

TABLE 3. ESTIMATED PERCENTAGES OF LEAF AREAS KILLED AND WINTER SURVIVAL OF SELECTED HYBRID STRAINS, MAIN EXPERIMENT STATION, WINTER OF 1939-40

Selection number	Parents	Leaf area killed	Survival
		Per cent	*Per cent*
R42-3-1-IV	Hairy Culberson × (Fulghum × Victoria)	85	90
R69-1-VI	Oklahoma 2898 × (Fulghum × Victoria)	85	90
R42-1-1-LXXIV	Hairy Culberson × (Fulghum × Victoria)	85	80
R73-I-I	Oklahoma 2900 × (Bond × Iogold)	96	80
R61-I-I	(Victoria × Richland 3313) × Tennessee 1922	98	80
R69-1-I	Oklahoma 2898 × (Fulghum × Victoria)	85	75
R69-1-II	Oklahoma 2898 × (Fulghum × Victoria)	85	75
R4-III-2	Coker 32-1 × Victoria	90	75
R69-2-VII	Oklahoma 2898 × (Fulghum × Victoria)	95	75
R42-3-1-VIII	Hairy Culberson × (Fulghum × Victoria)	96	70
R20-V-8	Tennessee 1922 × (Bond × Iogold)	90	68
R69-1-IV	Oklahoma 2898 × (Fulghum × Victoria)	85	65
R74-IV-18	Oklahoma 2900 × (Bond × Iogold)	98	65
R70-1-1-I	Oklahoma 2898 × (Fulghum × Victoria)	85	60
R42-3-1-II	Hairy Culberson × (Fulghum × Victoria)	90	60
R42-3-1-XI	Hairy Culberson × (Fulghum × Victoria)	90	60
R42-3-1-XXIV	Hairy Culberson × (Fulghum × Victoria)	90	60
R74-I-VI	Oklahoma 2900 × (Bond × Iogold)	96	60
R55-I-IV	Oklahoma 2900 × Boone	85	50
R55-I-V	Oklahoma 2900 × Boone	85	50
R69-2-I	Oklahoma 2898 × (Fulghum × Victoria)	85	50
R4-III-13	Coker 32-1 × Victoria	90	50
R21-VII-13	Tennessee 1922 × (Bond × Iogold)	95	50
R22-IV-I	Tennessee 1922 × (Bond × Iogold)	98	50
R20-V-19	Tennessee 1922 × (Bond × Iogold)	98	50
R74-IV-30	Oklahoma 2900 × (Bond × Iogold)	98	50
R20-V-25	Tennessee 1922 × (Bond × Iogold)	98	50
R19-1-V	Tennessee 1922 × (Bond × Iogold)	95	45
R40-II-17	Hairy Culberson × (Bond × Iogold)	95	45
R20-V-32	Tennessee 1922 × (Bond × Iogold)	98	45
R4-V-4	Coker 32-1 × Victoria	90	40
R70-1-1-II	Oklahoma 2898 × (Fulghum × Victoria)	90	40
R50-II-26	Victoria × Custis	95	40
R69-1-V	Oklahoma 2898 × (Fulghum × Victoria)	85	40
R23-II-I	Tennessee 1922 × (Fulghum × Victoria)	95	40
R39-1-IV	Hairy Culberson × Bond	95	40
R69-1-III	Oklahoma 2898 × (Fulghum × Victoria)	95	40
R21-IV-14	Tennessee 1922 × (Bond × Iogold)	98	40

became the basis for estimates on all rows. Check counts have shown that, with practice, one can estimate stands with fair accuracy. Because of the high mortality during the winter, it was possible to make accurate counts of survival in the spring. The records for the parents are shown in Table 2 and for the selections from hybrids in Table 3. Readings on amount of leaf area killed were taken twice, first on February 27 and again on March 5. Survival records were taken on April 1.

The amount of injury shown in Table 2 confirms Coffman's [5] and Murphy's [5] findings relative to the slight difference in hardiness between the more and less hardy varieties now available. Tennex, with 28 per cent, had the highest survival of any variety or selection. The Red Rustproof varieties, Texas 1415-12, Nortex, and Ferguson 922, and the crown-rust resistant parents, were completely killed.

Out of the 6,000 selections derived from the hybrids originally produced in 1936, some of which were in the fourth and others in the fifth generation in 1939-40, a large number showed less hardiness than the hardy parents; some showed as much hardiness; while a few showed more hardiness. Selections presented in Table 3 are limited to those that showed more hardiness than any of the parents.

The hardiness of the 38 selections presented in Table 3 was greater for this season than that of the near-by check rows (Lee), and superior to that of any of the parents. Some of these selections were not homozygous for crown-rust resistance, smut resistance, or for other important characters.

Injury Resulting From November, 1940, Freeze

Over 5,000 selections of individual plants were made from the hardy strains presented in Table 3, as well as from others in which one or more plants survived the winter of 1939-40 and possessed other desirable characters. On September 10 to 20, 1940, the seeds from these selections were planted mostly in 5-foot rows, using Lee as a check every tenth row. Duplicate plantings of 117 selections were made on October 17. Wherever possible, planting was at the rate of 5 gm. per row, the rate utilized for the checks.

With favorable rainfall and temperature, the stand was mostly good to excellent, and with continued favorable weather for growth, lasting almost 2 months, some of the selections, as

[5] See footnote 3. Coffman's data were incorporated in Murphy's paper.

well as some of the parents, were starting to joint by the first week in November. With the productive soil utilized, many selections made such luxuriant growth that clippings from measured parts of rows, taken early in November, yielded at the rate of over 5 tons per acre in green weight. Up to November 10, growth continued unabated and there was little or no opportunity for the plants to harden off. The mean temperature for September was 68.7° F., the lowest 37°; the mean for October was 63.8°, the lowest 34°; and the mean for the first 10 days of November was 53.6° and the lowest 31°, the low temperature prevailing for a short period on the night of November 7.[6]

There also occurred during the fall of 1940 the most severe epidemic of crown rust on young plants that the senior writer has recorded at the Main Station for any season of the year during a 22-year period. By the end of the first week in November, the rust was so common that every check row (Lee) showed some rust, the amount varying from a trace to more than 50 per cent of the leaf area.[7] In addition to crown rust, stem rust was also present although the amount and the distribution were much more limited.[8]

On the night of November 11, the temperature fell abruptly from 60° to 24° F. at the Main Station, and remained below freezing with almost no snowfall (0.4 inch) during most of the following 6-day interval. On November 13, it dropped to 11°, rose on the 14th to 12°, and on the 15th dropped to 9° (−12.8° C.). While such temperatures are rarely fatal to any variety of oats that has previously been hardened adequately, the absence of low, hardening temperatures prior to the freeze and the presence of rapidly growing, very tender, succulent tissue, made all oat varieties very sensitive to low-temperature injury.

While a severe November freeze following a prolonged period of growing conditions is quite exceptional for this region, the pattern as a whole duplicated, perhaps to a more marked degree than usual, what occasionally occurs in midwinter. Mild weather, interspersed between sharp drops of relatively short duration, are common characteristics of winter conditions in Arkansas.

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[6] Such plants as tomatoes, beans, and hybrid tea roses continued to grow and to bloom until November 10.

[7] All susceptible varieties of oats grown at the Main Station were also rusted. There was an estimated average infection in one field of Lee (approximately 2.4 acres) of 40 per cent of the leaf area.

[8] Rosen, H. R., "Stem Rust on Fall Sown Oats at Fayetteville, Arkansas." U. S. Bur. Plant Ind. Plant Dis. Rptr. 24: 382-383. 1940.

In Table 4 are presented estimates of the amount of injury on parent varieties and on a number of selections from Lee × Victoria (U. S. Department of Agriculture). These selections are included because they have been reported to combine hardiness with crown-rust resistance. Since the amount of

TABLE 4. ESTIMATED PERCENTAGES OF LEAF AREAS KILLED BY NOVEMBER, 1940, FREEZE, ESTIMATES OF AMOUNT OF GROWTH AT TIME OF FREEZE, AND SURVIVAL PERCENTAGES IN PARENT VARIETIES AND IN U. S. DEPARTMENT OF AGRICULTURE SELECTIONS FROM LEE × VICTORIA, MAIN EXPERIMENT STATION [1]

Variety or selection [2]	Leaf area killed	Amount of growth (Lee=1)	Survival, spring 1941
	Per cent		*Per cent*
Parents:			
Tennex	35	1	100
Tennessee 1922	40	1	100
Fulghum × Victoria (Stanton)	40	1.5	100
Oklahoma 2900	40	1	100
Oklahoma 2898	50	1	100
Hairy Culberson	50	1	100
Fulghum C. I. 3232	50	1	100
Custis	55	1	100
Lee	55	1	100
Coker 32-1	60	1	100
Texas 1415-12	60	1	95
Ferguson 922	60	1	100
Nortex	60	1	95
Lee × Bond (Adair-Ark. × 26)	70	1	85
Coker Fulgrain 33-19	70	1	95
Bond	80	1	20
Victoria	90	1	3
Boone	95	1.5	0
Victoria × Richland C. I. 3310	98	1.5	0
Victoria × Richland C. I. 3313	98	1.5	0
Bond × Iogold	98	1.5	2
Mutica Ukraina	98	2.5	0
Selections:			
Lee × Victoria C. I. 3392 (Letoria)	50	1	100
Lee × Victoria C. I. 3393 (Lenoir)	50	1.5	100
Lee × Victoria Ark. X-2-66-17-1	50	1.5	95
Lee × Victoria Ark. X-2-66-18-3	55	1.5	90
Lee × Victoria Ark. X-3-83-18-1	55	1 to 1.5	65
Lee × Victoria Ark. X-2-25-10-1 (DeSoto)	60	1	100
Lee × Victoria Ark. X-3-83-3-2	60	1.5	25
Lee × Victoria Ark. X-3-28-12-1 (C. I. 3694)	60	1 to 1.5	95
Lee × Victoria Ark. X-2-66-16-2	70	1	85
Lee × Victoria Ark. X-2-46-17-1	75	1.5 to 2	65
Lee × Victoria Ark. X-3-83-8-2	75	2	25
Lee × Victoria Ark. X-3-28-28-3	80	1	18

[1] Data taken November 27 on percentage of leaf area killed, and March 31, 1941, on spring survival.

[2] C. I. and other identifying numbers are given in Table 2.

growth for winter pasture is emphasized in the breeding program, estimates on the amount of such growth are also given. No known factor intervened between the time of injury and the taking of the records to influence the data on the percentage of injury shown.

The amount of leaf injury (Table 4) varied from about one-third of the leaf area in the hardiest variety, Tennex, to almost all of the leaf area in nonhardy varieties. While the primary interest in these figures concerns the marked reduction in green winter pasture occasioned by this freeze, in most of the varieties and selections in which the amount of leaf area injured was greater than 60 per cent, many plants were completely killed at the time when the notes were taken.

Survival percentages included in Table 4 agree in general with Murphy's [9] findings concerning the close relationship between amount of leaf injury and amount of survival. This relationship was more pronounced in the winter of 1940-41 than in the winter of 1939-40. (See Tables 2 and 3.)

It is to be expected that under field conditions there will be variation in amount of injury as well as in other characters, and some variation was noted in duplicate rows of numerous selections as well as in the checks. The amount of injury on check rows, as well as on other hardy susceptible strains and varieties, appeared to be correlated with the amount of rust infection. Where rust infection was greatest, there was usually the largest amount of winterkilling. Almost without exception, all hardy but rust-susceptible varieties planted early in September showed the greatest amount of crown rust, whereas the same varieties planted in October showed little or no rust. This variation in crown-rust infection was due to the fact that the early planted oats had a longer growing period prior to the November freeze, coupled with weather conditions more suitable for crown-rust infection.

There was a relative uniformity in the large amount of leaf area killed in the checks by the November freeze, compared with that of the rust-resistant selections planted at the same time. Out of 898 check rows of Lee, there were 24 rows (2.7 per cent) recorded as showing less than 50 per cent of the leaf area killed, 61 rows (6.8 per cent) recorded with more than 75 per cent killed, and the remainder, 813 rows (90 per cent), with 50 to 75 per cent killed. While difference in thickness of stand seemed to influence

[9] See footnote 3.

the amount of leaf killing, such influence was relatively unimportant. (See Figure 2.) The relative uniformity of killing in check rows may be seen in Figures 3 and 4.

In contrast to the checks, many of the hybrid selections suffered much less leaf killing. Check rows could be readily identified, even at a distance, by the large number of straw-colored or light brown, dead leaves. Data on the amount of leaf killing representative of the hardier selections following the November freeze are presented in Table 5.

The selections in Table 5 showed no greater injury than that exhibited by the hardiest parents, which was also true of many others not included in the table. The data also indicate that there was little, if any, correlation between winter injury and the amount of growth. Many selections that had made much more growth than Lee showed far greater hardiness. No data on the habit of growth are included in the table; however, a large proportion of the hardiest selections have an erect or semierect habit. Many selections with prostrate habit showed less inherent hardiness than some of the erect types, although there was an indica-

Figure 2. Winter injury on thick stands of check rows of Lee (staked), on a thin stand of Lee (indicated by arrow), compared with winter injury on selections of oat hybrids. Front row (left to right) consists of R 19-73, R 19-72, check, R 19-71, and R 19-70. Darker color of leaves in checks and in selections represents uninjured tissue. (Photographed November 20, 1940.)

Figure 3. General view of winter injury on check rows of Lee (staked), compared with winter injury on selections of oat hybrids. Lighter color of check rows represents mostly straw-colored, killed tissue. (Photographed December 5, 1940.)

Figure 4. Detailed view of winter injury on check row of Lee (staked), compared with winter injury on selections of oat hybrids. Front row (left to right) consists of R 19-10, check, R 19-9, and R 19-8. (Photographed November 28, 1940.)

TABLE 5. ESTIMATED PERCENTAGES OF LEAF AREAS KILLED BY NOVEMBER, 1940, FREEZE; ESTIMATES OF AMOUNT OF GROWTH AT TIME OF FREEZE; AND YIELDS OF SELECTED HYBRID STRAINS COMPARED WITH LEE (CHECKS), MAIN EXPERIMENT STATION

Selection number	Parents	Leaf area killed	Amount of growth (Lee=1)	Yield[1]	Yield nearest check (Lee)[2]
		Per cent		*Grams*	*Grams*
R1-5	Coker 32-1 × Victoria	35	1.5	202	107
R3-23	Coker 32-1 × (Victoria × Richland)	35	4	182	108
R3-35	Coker 32-1 × (Victoria × Richland)	40	2-3	223[3]	44
R3-38	Coker 32-1 × (Victoria × Richland)	35	3	152	44
R3-84	Coker 32-1 × (Victoria × Richland)	30	3	291	58
R3-107	Coker 32-1 × (Victoria × Richland)	35	2	174	91
R4-3	Coker 32-1 × Victoria	35	2	140	97
R4-38	Coker 32-1 × Victoria	35	2	177	58
R4-42	Coker 32-1 × Victoria	30	2	175	77
R4-46	Coker 32-1 × Victoria	30	2.5	159	97
R4-54	Coker 32-1 × Victoria	35	2	198	67
R4-87	Coker 32-1 × Victoria	35	2	267	57
R4-106	Coker 32-1 × Victoria	35	1.5	185	44
R10-8	Tennex × Bond	35	1.5	292	102
R11-62	Tennex × Bond	30	1.5	150	105
R12-17	Tennex × (Bond × Iogold)	30	2	175	78
R12-59	Tennex × (Bond × Iogold)	30	2	202	72
R12-81	Tennex × (Bond × Iogold)	30	1	185	66
R14-1	Tennessee 1922 × Bond	30	2.5	300	119
R18-5	Tennessee 1922 × (Victoria × Richland)	30	1.5	234	76
R19-20	Tennessee 1922 × (Bond × Iogold)	30	1.5	162	59
R19-29	Tennessee 1922 × (Bond × Iogold)	35	2-2.5	172	49
R19-31	Tennessee 1922 × (Bond × Iogold)	30	1.5-2	192	57
R19-35	Tennessee 1922 × (Bond × Iogold)	35	2-2.5	232	65
R19-37	Tennessee 1922 × (Bond × Iogold)	30	2-2.5	195	65
R19-69	Tennessee 1922 × (Bond × Iogold)	25	1.5-2	180	64
R19-73	Tennessee 1922 × (Bond × Iogold)	25	1.5-2	122	64
R19-82	Tennessee 1922 × (Bond × Iogold)	30	2	139	79
R20-7	Tennessee 1922 × (Bond × Iogold)	30	1.5	150	64
R20-16	Tennessee 1922 × (Bond × Iogold)	35	1.5	199	88
R20-17	Tennessee 1922 × (Bond × Iogold)	25	1.5	150	88
R20-25	Tennessee 1922 × (Bond × Iogold)	30	1	146	99
R20-32	Tennessee 1922 × (Bond × Iogold)	35	1.5	203	60
R20-43	Tennessee 1922 × (Bond × Iogold)	30	1-1.5	152	79
R20-44	Tennessee 1922 × (Bond × Iogold)	30	1.5	170	79
R20-46	Tennessee 1922 × (Bond × Iogold)	35	1.5	190	61
R20-47	Tennessee 1922 × (Bond × Iogold)	35	1.5	217	61
R20-49	Tennessee 1922 × (Bond × Iogold)	35	1.5	218	61
R20-51	Tennessee 1922 × (Bond × Iogold)	35	2	163	43
R20-52	Tennessee 1922 × (Bond × Iogold)	30	2	155	43
R20-59	Tennessee 1922 × (Bond × Iogold)	25	2	162	47
R20-64	Tennessee 1922 × (Bond × Iogold)	25	3	140	43
R20-66	Tennessee 1922 × (Bond × Iogold)	35	1.5	198	39
R20-68	Tennessee 1922 × (Bond × Iogold)	30	1.5-2	184	39
R20-74	Tennessee 1922 × (Bond × Iogold)	35	1.5	200	56
R20-78	Tennessee 1922 × (Bond × Iogold)	25	2	175	73

—*Continued.*

[1] Yields are for 5-foot rows.

[2] Since checks occurred on every tenth row, the farthest hybrid strain was not more than 4.5 feet from the nearest check.

[3] Average of two 5-foot rows.

TABLE 5. ESTIMATED PERCENTAGES OF LEAF AREAS KILLED BY NOVEMBER, 1940, FREEZE; ESTIMATES OF AMOUNT OF GROWTH AT TIME OF FREEZE; AND YIELDS OF SELECTED HYBRID STRAINS COMPARED WITH LEE (CHECKS), MAIN EXPERIMENT STATION—*(Continued)*

Selection number	Parents	Leaf area killed	Amount of growth (Lee=1)	Yield[1]	Yield nearest check (Lee)[2]
		Per cent		*Grams*	*Grams*
R20-78[3]	Tennessee 1922 × (Bond × Iogold)	----	----	161	65
R20-79	Tennessee 1922 × (Bond × Iogold)	25	2	198	73
R20-83	Tennessee 1922 × (Bond × Iogold)	30	1.5	169	72
R20-111	Tennessee 1922 × (Bond × Iogold)	25	1.5-2	206	69
R20-116	Tennessee 1922 × (Bond × Iogold)	30	1.5	211	65
R20-117	Tennessee 1922 × (Bond × Iogold)	35	1.5	198	60
R20-151	Tennessee 1922 × (Bond × Iogold)	30	1.5	205	73
R20-163	Tennessee 1922 × (Bond × Iogold)	30	1.5	176	55
R20-166	Tennessee 1922 × (Bond × Iogold)	30	1	177	66
R20-169	Tennessee 1922 × (Bond × Iogold)	25	1.5	158[5]	77
R20-175	Tennessee 1922 × (Bond × Iogold)	35	1.5	199	68
R20-180	Tennessee 1922 × (Bond × Iogold)	30	1.5	204	59
R20-181	Tennessee 1922 × (Bond × Iogold)	30	1.5	244	59
R20-183	Tennessee 1922 × (Bond × Iogold)	30	2	226	82
R20-196	Tennessee 1922 × (Bond × Iogold)	25	1.5	167	60
R20-200	Tennessee 1922 × (Bond × Iogold)	25	1	184	60
R20-226	Tennessee 1922 × (Bond × Iogold)	30	1	191	94
R20-262	Tennessee 1922 × (Bond × Iogold)	30	1	199	106
R20-326	Tennessee 1922 × (Bond × Iogold)	30	1.5	198	96
R29-6	Lee × (Bond × Iogold)	25	1	175	76
R40-20	Hairy Culberson × (Bond × Iogold)	35	1.5	190	69
R42-1	Hairy Culberson × (Fulghum × Victoria)	40	1.5	198	56
R42-2	Hairy Culberson × (Fulghum × Victoria)	40	1.5	208	56
R42-100	Hairy Culberson × (Fulghum × Victoria)	35	1	182	111
R42-128	Hairy Culberson × (Fulghum × Victoria)	30	1.5-2	218	98
R48-41	Victoria × Coker 32-1	25	1.5	234	145
R50-13	Victoria × Custis	35	1.5	174	94
R50-28s	Victoria × Custis	45	1-1.5	154[6]	81[7]
R55-134	Oklahoma 2900 × Boone	40	1.5-2	170	86
R55-249	Oklahoma 2900 × Boone	45	2-2.5	222	79
R55-361	Oklahoma 2900 × Boone	30	1.5	176	112
R55 Co.	Oklahoma 2900 × Boone	40	2-2.5	250	114
R65-11	(Bond × Iogold) × Coker 32-1	40	1.5	187	61
R65-19	(Bond × Iogold) × Coker 32-1	40	1-1.5	187	86
R65-57	(Bond × Iogold) × Coker 32-1	45	1.5	188	63
R65-133	(Bond × Iogold) × Coker 32-1	45	1.5	184	87
R65-218	(Bond × Iogold) × Coker 32-1	60	1.5-2	232	72
R65-261	(Bond × Iogold) × Coker 32-1	45	1	189	52
R73-23	Oklahoma 2900 × (Bond × Iogold)	35	1.5	183	112
R74-22	Oklahoma 2900 × (Bond × Iogold)	30	1.5	170	75
R83-11	(Lee × Bond) × (Fulghum × Victoria)	45	1-1.5	197	72
R91-11	Lee × Bond	50	1.5-2	212	93

[4] Duplicate row planted one month later.

[5] Average of two 5-foot rows.

[6] Average yield per 5-foot row of 20 rod-rows.

[7] Average yield per 5-foot row of 3 rod-rows of checks planted between 20 rod-rows of R50-28s.

tion that in a given selection or variety, a factor, such as very thick stand, that is conducive to erect growth is also conducive to greater winter injury. This may be due to greater exposure to wind action and to air temperatures existing several inches to a foot above soil level.

While the data in Table 5 indicate that hardiness in oats can be combined with excellent growth for winter pasture, such growth can only be obtained by taking advantage of good growing conditions usually prevalent in early fall in Arkansas. Since oats are not subject to Hessian fly injury, they can be planted earlier in the fall than barley or wheat, which may enable them to make enough growth for winter pasture. Experience has shown that unless oats are planted by the middle of September in northern and hilly parts of Arkansas, and by early October in the remainder of the state, their superiority over wheat and barley for winter pasture is likely to be lost. In other words, the greater growth of some selections over hardy parent varieties is largely due to their faster growth in the early fall and not necessarily due to any marked ability to grow at low temperatures.

Since some of the selections that survived the winter of 1939-40 were in the F_4 generation and others in the F_5, they were still segregating for various factors, which probably accounts for the fact that several selections, derived from those that showed high percentages of survival in 1939-40, did not show much hardiness in the November, 1940, freeze. On the other hand, some came through both of these periods with marked superiority over other selections and over all parent varieties, particularly selections derived from crosses between Tennessee selections [10] from Fulghum winter type C. I. 2499 and Bond × Iogold (U. S. Department of Agriculture). Several of these combinations, represented in Table 5 by the series of R19, R20, and R21, have yielded selections that made good fall growth and possessed hardiness coupled with resistance to smuts, to crown rust, and, in many, to stem rust also. Since the most advanced of these are only in the F_6 generation, segregation for one or more characters is still continuing. However, as single plant selections have been made three times in successive generations of some crosses, there are a few that now approach homozygosity or have reached it for desired characters.

The hardiness shown for the selections in Table 5 can, in part, be attributed to their rust resistance. In the presence of the

[10] Made by N. I. Hancock, Associate Agronomist, Tennessee Agricultural Experiment Station.

severe epidemic of crown rust, the check variety, Lee, appeared to have suffered more winter injury wherever the rust was most abundant. This, however, does not explain the high degree of hardiness of certain selections that were fully as susceptible to crown rust as Lee. The degree of influence of crown rust on hardiness was difficult to evaluate primarily because of the variation in the amount of rust. The data, however, indicated that in hardy but rust-susceptible varieties there was a positive correlation between the amount of injury occasioned by rust and the subsequent amount of winter injury, although the complete killing of plants, found by Murphy [11] in such a variety as Lee, when 30 per cent of the leaf area was infected under artificial conditions, was not observed under the field conditions of November, 1940.[12] Conversely, nonhardy but rust-resistant varieties, such as Boone and Bond × Iogold, were almost completely killed. It appears, therefore, that while rust infection is conducive to reduction in hardiness, rust resistance, unless coupled with a high degree of hardiness, is insufficient to protect the plants against winter injury.

While the yield data obtained from short rows possess little accuracy so far as yields per acre are concerned, comparative yield data of the selected strains and of the check rows of Lee may be considered as showing significant differences. Yields of the checks, Lee, ranged from 39 to 145 gm. per 5-foot row, while yields of selected strains ranged from 122 to 300 gm.[13] Although it is doubtful if such yields would be obtained in adequate-sized blocks for a series of years, the data indicate that many of these disease-resistant oats possessed much higher yielding qualities in 1940-41 than Lee, a variety considered at present to be one of the best available for the region where these tests were conducted.

Summary

During the winter of 1939-40, one of the most severe on record for Arkansas, there were growing on the Main Experiment Station some 6,000 selections of oat hybrids, produced by the writers, as well as all parent varieties used in hybridizing. Some

[11] See footnote 3.

[12] The field of Lee, previously mentioned (footnote 7) as showing an estimated 40 per cent severity of infection, showed very little reduction in stand.

[13] These high yields were duplicated, in numerous instances, by the same or by sister selections grown at the same time at the Rice Branch Experiment Station.

of these parents represent the hardiest varieties available, and include Hairy Culberson, Custis, Lee, Tennex, Fulwin, and Tennessee 1922. The percentage of survival for all parents was very low, ranging from 28 for Tennex to 0 for a number of other varieties.

Most of the selections showed no greater hardiness than the parents, and some not as much. Thirty-eight selections showed much more hardiness than any of the parents, ranging in survival from 40 to 90 per cent.

Over 5,000 selections of individual plants were made from the hybrids that survived the winter of 1939-40 and that possessed other desired characters, particularly crown-rust resistance. The seeds from these were planted early in September, 1940, and, with favorable growing conditions lasting for 2 months, the stands were good and the numerous selections made such luxuriant growth that clippings taken in early November indicated yields of over 5 tons to the acre in green weight. These selections represented the F_5 and F_6 generations.

Along with good growing weather, including ample rain, there developed a severe epidemic of crown rust. All susceptible selections and susceptible parent varieties became infected, the degree of severity varying from a trace to over 50 per cent.

While the plants were growing rapidly, some starting to joint, and before they had an opportunity to harden off, the temperature dropped to 24° F. on November 11 and remained below freezing during most of the following 6-day interval, reaching a low of 9° F. (−12.8° C.).

Many of the nonhardy selections and parents were completely killed, while the hardier parents showed leaf injury varying from 35 to 70 per cent. Some of this injury could be attributed to a reduction in hardiness caused by severe crown-rust infection. Numerous hardy selections showed appreciably less injury than the hardiest parents. Among these are some that made considerably more growth for winter pasture than the hardy parents, and are homozygous for resistance to crown rust, some to both crown and stem rust, and to smuts.

The data indicate that it is possible to breed oats possessing considerable hardiness, and that such hardiness can be coupled with excellent growth for winter pasture, with rust and smut resistance, and with good grain yields.